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BEFORE THE ARIZONA CORPORATION COMMISSION

COMMISSIONERS
KRISTIN K. MAYES, CHAIRMAN
GARY PIERCE
SANDRA D. KENNEDY
PAUL NEWMAN
BOB STUMP

Arizona Corporation Commission
DOCKETED
JUN - 7 2010
DOCKETED BY

IN THE MATTER OF THE APPLICATION OF HUALAPAI VALLEY SOLAR LLC, IN CONFORMANCE WITH THE REQUIREMENTS OF ARIZONA REVISED STATUTES §§ 40-360.03 AND 40-360.06, FOR A CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY AUTHORIZING CONSTRUCTION OF THE HVS PROJECT, A 340 MW PARABOLIC TROUGH CONCENTRATING SOLAR THERMAL GENERATING FACILITY AND AN ASSOCIATED GEN-TIE LINE INTERCONNECTING THE GENERATING FACILITY TO THE EXISTING MEAD-PHOENIX 500kV TRANSMISSION LINE, THE MEAD-LIBERTY 345kV TRANSMISSION LINE OR THE MOENKOPI-EL DORADO 500kV TRANSMISSION LINE.

CASE NO. 151

Docket No. L-00000NN-09-0541-00151

NOTICE OF FILING
STAFF'S DIRECT TESTIMONY

Staff of the Arizona Corporation Commission ("Staff") hereby files the Direct Testimony of Laura A. Furrey of the Utilities' Division.

RESPECTFULLY SUBMITTED this 7th day of June, 2010.

Charles H. Hains
Arizona Corporation Commission
1200 West Washington Street
Phoenix, Arizona 85007
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Original and twenty (20) copies of the foregoing filed this 7th day of June, 2010 with:

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By Monica A. Martinez

BEFORE THE ARIZONA CORPORATION COMMISSION

KRISTIN K. MAYES
Chairman
GARY PIERCE
Commissioner
PAUL NEWMAN
Commissioner
SANDRA D. KENNEDY
Commissioner
BOB STUMP
Commissioner

IN THE MATTER OF THE APPLICATION OF HUALAPAI VALLEY SOLAR LLC, IN CONFORMANCE WITH THE REQUIREMENTS OF ARIZONA REVISED STATUTES §§ 40-360.03 AND 40-360.06, FOR A CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY AUTHORIZING CONSTRUCTION OF THE HVS PROJECT, A 340 MW PARABOLIC TROUGH CONCENTRATION SOLAR THERMAL GENERATING FACILITY AND AN ASSOCIATED GEN-TIE LINE INTERCONNECTING THE GENERATING FACILITY TO THE EXISTING MEAD-PHOENIX 500kV TRANSMISSION LINE, THE MEAD-LIBERTY 345kV TRANSMISSION LINE OR THE MOENKOPE-EL DORADO 500 kV TRANSMISSION LINE.	DOCKET NO. L-00000NN-09-0541-0151

DIRECT TESTIMONY

OF

LAURA FURREY

ELECTRICITY SPECIALIST

UTILITIES DIVISION

ARIZONA CORPORATION COMMISSION

JUNE 07, 2010

EXECUTIVE SUMMARY
HUALAPAI VALLEY SOLAR LLC
DOCKET NO. L-00000NN-09-0541-00151

Staff conducted a literature review on the use of wet, dry, and hybrid cooling systems in new power plants. Although general conclusions may be drawn from the literature, Staff is not making any recommendations regarding the method of cooling to be used in this application. This review is provided for informational purposes.

INTRODUCTION

Q. Please state your name, occupation, and business address.

A. My name is Laura Furrey. I am an Electricity Specialist employed by the Arizona Corporation Commission ("ACC" or "Commission") in the Utilities Division ("Staff"). My business address is 1200 West Washington Street, Phoenix, Arizona 85007.

Q. Briefly describe your responsibilities as an Electricity Specialist.

A. In my capacity as an Electricity Specialist, I provide recommendations to the Commission in a variety of electricity-related cases, including renewable energy projects and demand side management programs. I also perform research on energy-related topics as needed.

Q. Please describe your educational background and professional experience.

A. In 2002, I graduated from California Polytechnic State University – San Luis Obispo, receiving a Bachelor of Science degree in Environmental Engineering. In 2003, I joined Stanley Consultants, Inc. in Phoenix, Arizona as a civil designer. In 2005 I became a certified professional engineer in the State of California. In 2008, I graduated cum laude from Vermont Law School with a Juris Doctor degree, focusing on energy and environmental law. In 2008, I became a member of the State Bar of Arizona and began working with the American Council for an Energy-Efficient Economy in Washington, DC. In 2010, I became employed with the Staff of the Commission as an Electricity Specialist in the Telecom and Energy Unit. Since that time, I have attended various seminars and classes on general regulatory and energy issues.

Q. What is the scope of your testimony in this case?

A. My testimony is limited to providing Staff's attached literature review regarding wet cooling, dry cooling, and hybrid cooling systems and the associated economic and review, these are general conclusions and are not intended to provide the basis of a Staff recommendation with regard to this application.

Q. Does this conclude your Direct Testimony?

A. Yes, it does.

ATTACHMENT A

USE AND ASSOCIATED COSTS OF WET, DRY, AND HYBRID COOLING SYSTEMS IN NEW POWER PLANTS

UTILITIES DIVISION STAFF

ARIZONA CORPORATION COMMISSION

APRIL 14, 2010

Use and Associated Costs of Wet, Dry, and Hybrid Cooling Systems in New Power Plants
(April 14, 2010)

Introduction

In all thermal (Rankine-cycle) power plants, whether fossil-, nuclear-, or solar-fueled, heat is used to boil water into steam to run a steam turbine to generate electricity. The exhaust steam from the generator must be cooled prior to being heated again and turned back into steam.

Cooling System Options[1]

Cooling can be done with water (wet cooling) or air (dry cooling), or a combination of both (hybrid cooling). Thermal power plants (fossil, nuclear and solar[2]) must use some form of cooling to condense the steam which spins the turbine. From a cost and efficiency perspective, the preferred method, thus far, has been the use of large quantities of cooling water.[3] In 2000, thermoelectric power accounted for 3.3 percent of total freshwater consumption (3.3 billion gallons per day) and represented over 20 percent of nonagricultural water consumption.[4]

Once-Through Cooling Systems (Wet)

In a once-through cooling system, water from an external water source passes through the steam cycle condenser and is then returned to the source at a higher temperature with some level of contaminants. This system withdraws a significant amount of water, but consumes little at the plant site (with some evaporation occurring after the water is returned to its source).[5]

Recirculating Cooling Systems (Wet)

In recirculating (or closed-loop) wet systems, smaller amounts (typically 2 to 3% of the amount withdrawn for once-through cooling) are taken into the plant, but the majority is evaporated in the cooling equipment (in mechanical or natural draft cooling towers or a cooling pond), with very little water returned to the source. Water withdrawn from a local source is circulated continuously through the cooling system. The cooling system must be replenished with "make-up water" to replace water lost to evaporation and blowdown.[6,7]

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[1] See Appendix A for illustrative representations of all cooling system types.
[2] Concentrating solar power (CSP) plants using parabolic trough, linear Fresnel, and power tower technologies must use some form of cooling. Photovoltaic (PV), concentrating PV, and dish-engine solar plants are not thermal cycle plants and do not require water for cooling. See Solar Energy Industries Association, Utility-Scale Solar Power, Responsible Water Resource Management (October 2, 2009) at 1. Available at www.seia.org.
[3] U.S. Department of Energy, Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water, at 63 (December 2006), hereinafter DOE 2006.
[4] DOE 2006 at 9.
[5] Water Requirements for Existing and Emerging Thermoelectric Plant Technologies, DOE/NETL-402/080108, August 2008 (April 2009 Revision), at 3-4. Available at http://www.netl.doe.gov/energy-analyses/pubs/WaterRequirements.pdf, hereinafter DOE 2009.
[6] Blowdown refers to water that must be removed from the system with removal rates set to control scaling, fouling, and corrosion by limiting the buildup of impurities in the circulating water.
[7] California Energy Commission, Comparison of Alternate Cooling Technologies for California Power Plants Economic, Environmental and Other Tradeoffs, at 1-6 (February 2002), hereinafter CEC Report.

In hybrid wet-dry systems, both wet and dry components are included and can be used separately or simultaneously for either water conservation or plume abatement[15] purposes. Depending on system configuration (of which there are many options), water consumption can approach that of recirculating wet systems or be much lower. Design studies have ranged from 30 to 98% reduction in water use compared to all-wet recirculating systems.[16]

Impacts of cooling system use at power plants in the US

The amount of cooling required by any thermal power plant is determined by its thermal efficiency. The bigger the temperature difference between the internal heat source and the external environment where the surplus heat is discarded, the more efficient the process in achieving mechanical work, such as turning a steam turbine.[17] This is because the cooling water (or air) temperature affects the level of vacuum at the discharge of the steam turbine. As the cooling medium temperature decreases, a higher vacuum can be produced and additional energy can be extracted.[18] It is, therefore, desirable for a power plant to have a high internal temperature and a low external or environmental temperature. [19]

The amount of cooling water required depends on the generating and cooling technologies, as well as the ambient meteorological conditions at the plant.[20] A range of water withdrawal and consumption (including downstream evaporation of once-through or open-loop systems) for typical thermal power plants and cooling systems is presented below. The lower end of the flow rate range corresponds to higher temperature differentials, and vice versa.[21]

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[15] Plume abatement is achieved by passing the saturated exhaust from a conventional wet cooling tower is through an indirect dry cooling system located above the cooling tower to prevent the atmospheric release of a visible plume. Depending upon the temperature and humidity of the surrounding air, the saturated exhaust can form a visible plume which may be unaesthetic, might impair visibility, or may cause icing on nearby roadways.

[16] CEC Report at 1-7 (citing Mitchell, R. D. Survey of Water-Conserving Heat Rejection Systems. 1989. Palo Alto, CA, Electric Power Research Institute).

[17] World Nuclear Association, Cooling Power Plants, updated February 2010. Available at http://www.world-nuclear.org/info/cooling_power_plants_inf121.html, hereinafter World Nuclear Association.

[18] U.S. Department of Energy, Energy Penalty Analysis of Possible Cooling Water Intake Structure Requirements on Existing Coal-Fired Power Plants at 2 (October 2002), hereinafter DOE 2002.

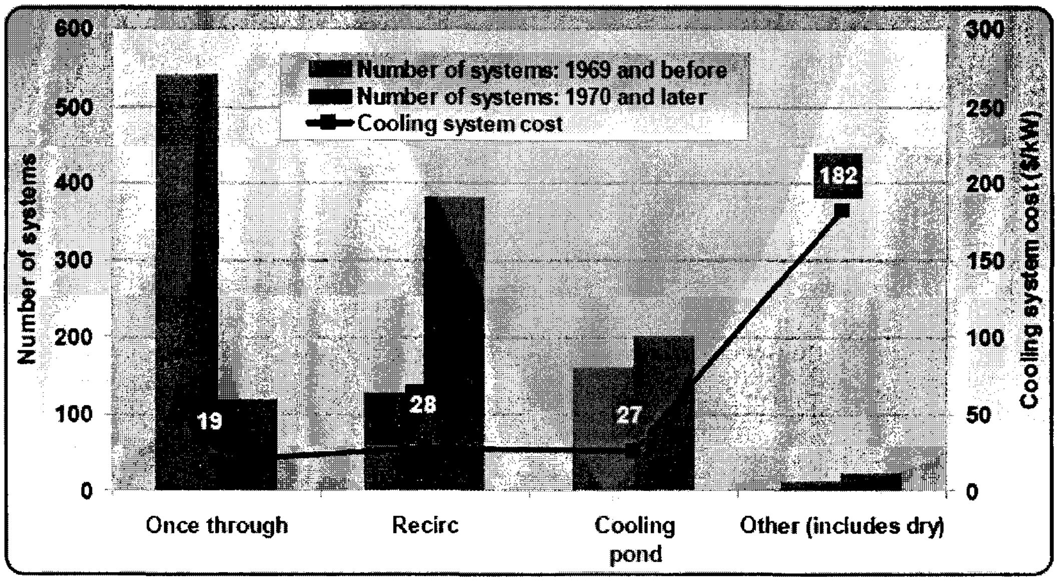
[19] World Nuclear Association.

[20] DOE 2006 at 63.

[21] EPRI Volume 3 at 3-1.

Generally, wet recirculating systems are roughly 40% more expensive than once-through systems, while dry cooling systems are 3 to 4 times more expensive than a wet recirculating system.[29] For all thermal systems, water cooling has, thus far, been more economical than air cooling because water cooling has a low capital cost and higher thermal efficiency.[30] Because water temperatures tend to be lower than ambient air temperatures, condensers in wet cooling systems can be smaller in size while once-through systems do not require the cooling towers associated with wet and dry recirculating systems.

Average total cost and number of cooling systems for fossil/biomass-fueled steam plants in the U.S. (as of 2005)[31]



Wet Cooling System Costs[32]

The two major elements of a recirculating wet cooling system are the cooling tower (which is not needed in a once-through system) and the surface condenser (which is likely smaller in a once-through cooling system due to lower cooling water temperatures). The equipment included in the cost estimate evaluated in the CEC report consisted of everything downstream of the turbine flange and includes the costs of engineering, site preparation, erection, installation, and testing. The base system chosen to represent recirculating wet cooling is the mechanical draft, cross-flow wet cooling tower in the traditional in-line arrangement of cells to form a rectangular tower.[33]

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[29] DOE 2009 at 5 (citing R.Tawney, Z. Khan, J. Zachary (Bechtel Power Corporation), "Economic and Performance Evaluation of Heat Sink Options in Combined Cycle Applications", Journal of Engineering for Gas Turbines and Power, April 2005, Vol. 127). It is unclear whether this refers to capital costs or lifetime costs.

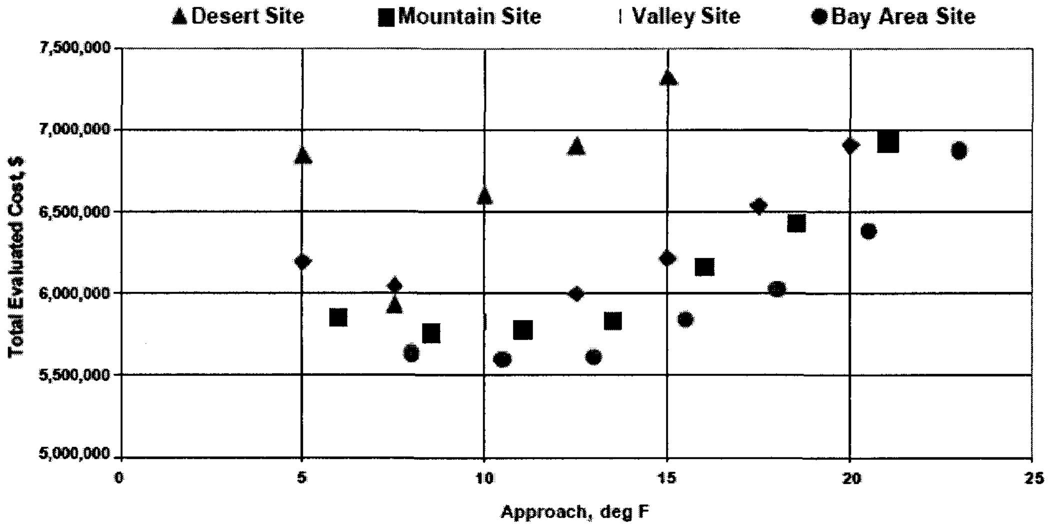
[30] DOE CSP at 4.

[31] DOE 2009 at 5 (adapted from U.S. Department of Energy, Energy Information Administration (EIA). Form EIA-767: Annual Steam-Electric Plant Operation and Design Data. 2005 data).

[32] For engineering assumptions, see CEC Report at 5-9 – 5-11.

[33] CEC Report at 5-17.

Wet Cooling System Total Evaluated Cost vs. Approach[40] for Minimum Evaluated Cost Design (for New 500-MW Facilities with 170-MW Steam Cycle)[41]



Capital costs for wet systems generally tend to decrease as the approach temperature increases (because the tower and condenser may be smaller due to the higher temperature differential). However, higher approach temperatures can lead to higher circulating water flows and inlet temperatures, resulting in higher condenser costs. Additionally, the higher wet bulb temperatures at the Desert site lead to higher condenser inlet temperatures (more so than for the other sites) substantially increasing condenser costs.

<u>Dry Cooling System Costs</u>
The capital costs included in a new dry cooling system include the base system for dry cooling. The CEC report evaluated a direct system with a mechanical draft air-cooled condenser (ACC). Additional costs include installation and erection costs (which vary depending on the design temperature, size and site), electrical wiring and hookup (which range from about 3.5 to 7.5% of cooling system costs), auxiliary cooling (about 7.5% of cooling system costs), and additional items, such as sensors, controls, fire and lighting protection, finned surface cleaning equipment, and finish painting.[42]

Dry cooling systems, as well as hybrid cooling systems, are larger and mechanically more complex than corresponding wet cooling systems. They require a larger heat transfer surface area and more fans (which means more electrical motors, gearboxes and drive shafts) increasing capital and operating costs.[43]

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[40] "Approach" is the temperature differential between the cold water entering the condenser and the inlet wet bulb temperature, which is typically in the range of 8-15°F. See CEC report at 2-7.
[41] CEC Report at 5-22.
[42] CEC Report at 5-24 – 5-26.
[43] Micheletti and Burns, Emerging Issues and Needs in Power Plant Cooling Systems at 5. Available at http://www.netl.doe.gov/publications/proceedings/02/EUW/Micheletti_JMB.PDF

In general, a dry cooling system is designed to maintain a certain back pressure for a given heat load at a given ambient temperature.[52] When the ambient temperature exceeds the design temperature, the back pressure will be higher than design, resulting in a higher plant heat rate. For a steam cycle with a fixed heat input, this translates to a lower power output. If the heat input can be increased, the plant output may be maintained but fuel costs will increase.

Additionally, steam turbines are designed with an upper limit on back pressure. As this limit is reached (at times of high ambient temperature) steam flow must be reduced to avoid damage to the turbine. Reduced steam flow leads to reduced power output (lost MWh) from the steam cycle. In the case of a combined-cycle unit, if exhaust gas does not have an outlet alternative to the heat recovery steam generator (HRSG) the output from the combustion turbine will be reduced as well, further impacting energy output.[53]

In a more detailed penalty analysis, the CEC report demonstrates that the types of costs are highly dependent on dry-cooling system design criteria. For example, a system designed with a low operating pressure and a low ITD, may have very high capital and evaluated power costs when compared to a system designed with a higher operating pressure and/or ITD. However, if the latter system is forced to operate at conditions beyond its design criteria, for example at a much lower ITD as ambient temperatures increase and approaching maximum back pressure, capacity and heat rate penalties can get very high, leading to significant capacity reductions and increased costs per MWh.[54]

Conclusion

Power plants operating at high thermal efficiencies require less cooling water and cost less to operate. High thermal efficiencies are not as easily achieved with dry cooling systems because ambient dry bulb temperatures are always higher than ambient wet bulb temperatures. There is a tradeoff between steam flow, water use, and energy output under the various cooling systems which need to be evaluated on a site-specific basis, placing a value on water, fuel, emissions, and the subsequent effects on electric rates.

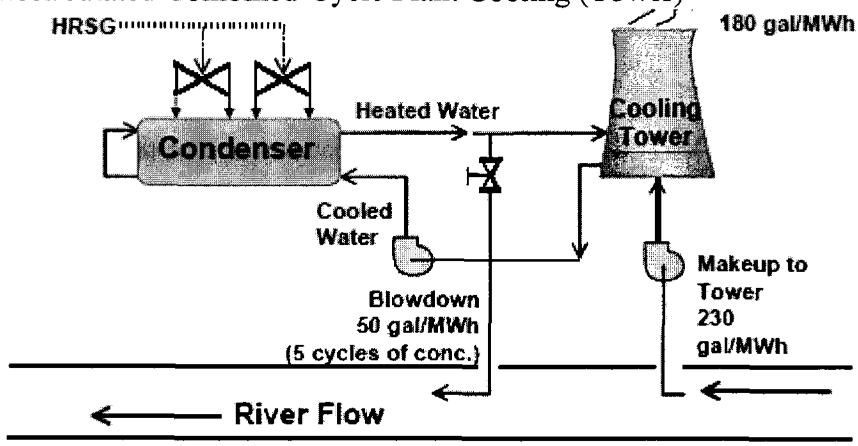
Resources, Inc., Albuquerque, NM, El Paso Electric Co., El Paso, TX, San Diego Gas & Electric Co., San Diego, CA, Southern California Edison Co., Rosemead, CA, Tri-State Generation & Transmission Association, Inc., Westminster, CO, and Xcel Energy Services, Inc., Denver, CO: 2008. 1016342.

[52] CEC Report at 5-30. Design ambient temperature is normally set at a value well below maximum temperature expected at site during hottest periods of the year.

[53] CEC Report at 5-31.

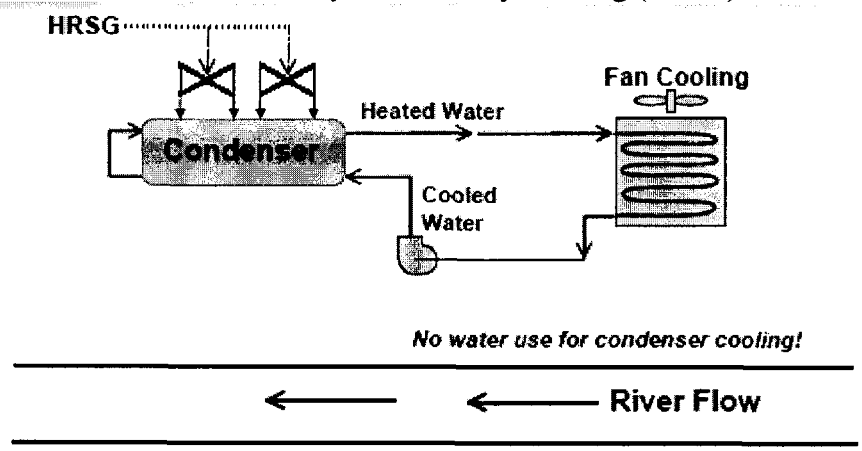
[54] For a detailed analysis of various penalty scenarios, see CEC Report at 5-31 – 5-39.

Recirculated Combined-Cycle Plant Cooling (Tower)



HRSG: heat recovery steam generator

Recirculated Combined-Cycle Plant Dry Cooling (Direct)



APPENDIX B: WORLEYPARSONS CAPITAL COST SUMMARY[58]

Case	Base	ACC 1	ACC 2	ACC 3	Hybrid 1	Hybrid 2	Hybrid 3
Description	Cooling tower	35 ITD	40 ITD	45 ITD	250 MW ACC	200 MW ACC	150 MW ACC
Number of cooling tower cells	11				3	4	4
Number of ACC cells		42	40	35	35	25	20
HTF Pumps Estimated Capital Cost	$3,000,000	$3,300,000	$3,300,000	$3,300,000	$3,150,000	$3,150,000	$3,150,000
Boiler Feed Water Pumps Estimated Capital	$2,300,000	$2,400,000	$2,400,000	$2,400,000	$2,320,000	$2,320,000	$2,320,000
Steam Generator Heat Exchanger Estimated Capital Cost	$12,500,000	$14,100,000	$14,100,000	$14,100,000	$13,400,000	$13,400,000	$13,400,000
Solar Field Sizing [1]	$410,000,000	$463,000,000	$463,000,000	$463,000,000	$441,000,000	$441,000,000	$441,000,000
Cooling tower Estimated Cost	$4,275,000				$1,025,000	$1,475,000	$1,675,000
Cooling tower basin + installation Estimated Cost	$1,500,000				$350,000	$450,000	$500,000
Circulating Water pumps + installation Estimated Cost	$600,000				$265,000	$350,000	$375,000
Surface Condenser + installation Estimated Cost	$3,500,000				$700,000	$875,000	$975,000
Circulating Water piping Estimated Cost	$1,300,000				$750,000	$950,000	$1,050,000
Circulating Water piping installation Estimated Cost	$520,000				$400,000	$450,000	$500,000
ACC Equipment Only		$42,500,000	$36,900,000	$33,300,000	$28,260,000	$21,860,000	$19,620,000
ACC Installation		$12,075,000	$11,500,000	$10,062,500	$10,062,500	$7,187,500	$5,750,000
Closed cycle aux cooler (installed)		$450,000	$450,000	$450,000			
Water Treatment Capital Cost-Installed	$21,158,000	$2,500,000	$2,500,000	$2,500,000	$11,116,000	$11,116,000	$11,116,000
TOTAL CAPITAL COST with Solar Field Size Consideration	**$460,653,000**	**$540,325,000**	**$534,150,000**	**$529,112,500**	**$512,798,500**	**$504,583,500**	**$501,431,000**
TOTAL CAPITAL COST without Solar Field Size Consideration	**$50,653,000**	**$77,325,000**	**$71,150,000**	**$66,112,500**	**$71,798,500**	**$63,583,500**	**$60,431,000**

Solar field capital cost applies to the case where the solar field size is increased to offset lower cycle efficiency.

[58] WorleyParsons. FPLE - Beacon Solar Energy Project: Dry Cooling Evaluation. WorleyParsons Report No. FPLS-0-LI-450-0001. WorleyParsons Job No. 52002501. at 7, February 2008.